Kansas Seismic Action Plan

September 26, 2014

Prepared by

Department of Health and Environment
Corporation Commission
Geological Survey

State of Kansas Seismic Action Plan
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Background

In January 2014, Kansas Governor Sam Brownback established a task force led by the Kansas Geological Survey (KGS), and comprised of the KGS, Kansas Corporation Commission (KCC), and Kansas Department of Health and Environment (KDHE). He directed the task force to study and develop a State Action Plan for addressing seismic activity in the State. While seismic activity can be associated with activities as common as blasting rock for quarries and construction, this Plan specifically focuses on seismic activity related to earthquakes.

Seismic activity in Oklahoma, central Arkansas, and south-central Kansas heightened concerns about a connection between human activities and felt earthquakes. Seismicity in other states has been linked to mining, hydrocarbon reservoir production, geothermal development, waste disposal via underground injection wells, as well as naturally occurring seismicity. Much contemporary attention in the midcontinent has focused on the possible link between wastewater disposal wells and seismicity. The majority of the disposal wells in Kansas are associated with salt water disposal from oil and gas production.

Previous studies demonstrate that earthquakes can be triggered by fluid injection (National Research Council, 2012). Research from the U.S. Geological Survey (USGS) has found that "at some locations the increase in seismicity coincides with the injection of wastewater in deep disposal wells" (Hayes, 2012). Fluid injection near a fault under a certain set of conditions can cause a fault to move, resulting in an earthquake.

Significant amounts of salt water are produced along with oil and natural gas in the United States, including Kansas. This salt water is generally injected back into the deep subsurface for disposal or as part of enhanced oil recovery (EOR) projects. These injection wells, for regulatory purposes, are referred to as Class II injection wells and are designed and permitted to ensure potential drinking water supplies are not compromised. In Kansas, Class II injection wells are regulated by the KCC. There are approximately 16,000 Class II wells in Kansas used to inject waste fluids from oil and gas operations. The majority of Class II wells in Kansas are used for EOR projects and approximately 5,000 serve as disposal wells.

The injection of salt water should not be confused with hydraulic fracturing (or "fracking"). While hydraulic fracturing does create micro seismic events (generally less than a magnitude 1.0 and too small to feel), the events are nearly always highly localized and not considered a significant hazard. Felt earthquake activity (generally greater than a magnitude 2.5) in the midcontinent resulting from hydraulic fracturing has been reported from only a handful of locations. In the midcontinent, the USGS has stated there is "no evidence to suggest hydraulic fracturing itself is the cause of the increased rate of earthquakes" (Hayes, 2012).

Oil and gas is a cornerstone industry in Kansas generating nearly $4.3 billion each year, and employs 118,000 Kansans each day. In developing the State Action Plan, the task force considered the safety of all Kansans, along with the impacts to industry and the environment.

The taskforce has met with seismologists, geologists, and others who are studying the seismic activity. Additionally, a public meeting was held in Wichita on April 16, 2014, with presentations by seismic experts and input by a variety of stakeholders (see attached list of attendees). Public comment was received on a draft seismicity plan until May 16, 2014. Based on all input received, the taskforce recommends the following Seismic Action Plan.

Plan

The Seismic Action Plan consists of two major components – a plan for Enhanced Seismic Monitoring and a Response Plan. A flow chart of the Plan is included on Page 7, and a narrative follows.

I. Enhanced Seismic Monitoring

Kansas currently has no state-supported seismic network. The state relies on two permanent seismic monitors located in Kansas and operated by the US Geological Survey (USGS), as well as seismic monitors in Oklahoma operated by the Oklahoma Geological Survey (OGS). In addition, USGS has recently installed low-sensitivity temporary (months of operation) monitors at several locations in south-central Kansas. The data provided by all of these sensors has indicated an uptick in Kansas' earthquake activity. While the additional sensors have provided added sensitivity, the numbers of measured events are also increasing. Even with the additional monitors, however, the surface locations (epicenters) and the depths of the earthquakes (focus) are imprecise (though improvements in future locations are expected with the recent installation of USGS temporary instrumentation). Both of these parameters are needed to better delineate and more fully understand the possible triggering mechanisms behind the earthquakes.

A. Permanent Network

KGS has proposed a multi-station permanent network to allow all earthquakes in Kansas of magnitude greater than 1.5 to be detected and located. If located properly, six permanent stations would provide statewide coverage. A map of proposed locations is shown in Figure 1.

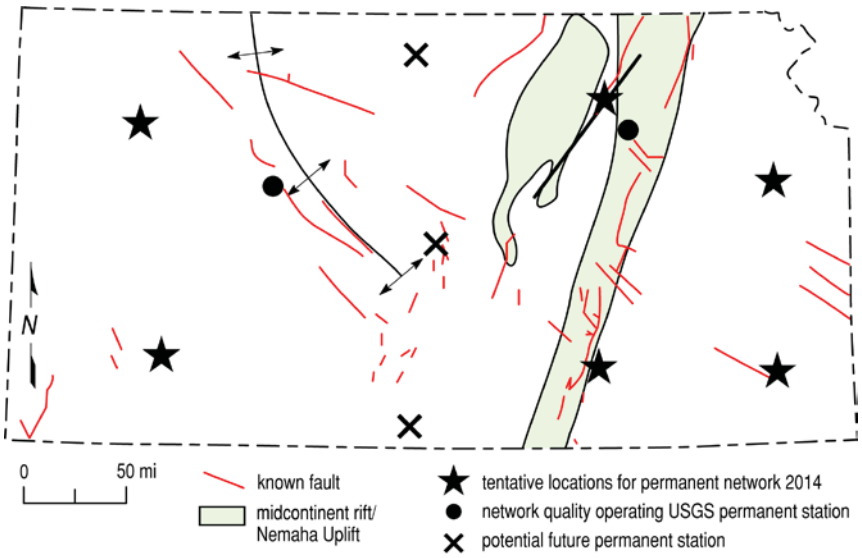


Figure 1 – Proposed Permanent Seismic Network Sites

The permanent network would cost around $200,000 to purchase and install. Annual operating costs would be approximately $80,000. The Kansas Legislature, through the Kansas Adjutant General's Office, directed a total of $160,000 in one-time funds from fiscal year 2014 to this project. The KGS plans to pursue additional funding along with continued operational funding in SFY 2015. There was near unanimity among stakeholder comments for establishing and operating a permanent regional network in Kansas to develop background data, as well as ascertain with greater accuracy the location and depth of earthquakes.

Therefore, it is the recommendation of the Task Force that the State fully fund the purchase, installation, and operation of a permanent seismic network in the locations recommended by KGS.

B. Portable Seismic Array

A portable seismic array would allow the KGS to quickly deploy a six station network into an area with significant seismic activity and dramatically improve the focus of the activity. If a disposal well is considered a potential source, the array, in conjunction with flow data at the well head, would help to verify whether the well could be triggering earthquake activity. If no correlation is evident between the seismic activity and injection, other causes – including natural activity – would be investigated.

KGS estimates the cost of a portable array to be approximately $150,000 with an annual operating cost of $20,000 per 3 month deployment.

While not as important as establishing a permanent seismic network, the Task Force recommends the State fund a portable network to better understand the cause of localized earthquakes.

II. Response Plan

A. The occurrence of a recorded seismic event will trigger the Response Plan. KGS will determine the magnitude, location, and depth of the event.

B. KGS will determine the seismic action score (SAS) for the event by adding the numeric value of the magnitude of an earthquake to the sum of the individual weighted scores for each of the variables listed in Table 1.

$$\mathbf{SAS = Magnitude + Score_{felt} + Score_{structure} + (2 \times Score_{number}^{3}) + Score_{local\ recursion}^{3} + Score_{recursion\ regional} + Score_{recursion\ time}}$$

The formula attempts to weight two significant discriminators of seismic events:

1. Risk – The risk component is captured by the "felt" and "structure" variables. If an event is felt or if a usable structure is within 6 miles of the event, there is some risk of property damage which heightens the importance of the event. Conversely, if the event is not felt or there are no usable structures near, risk to property is minimal and lessens the immediate need for response.

2. Clustering and timing – If seismic events are clustered over a short period in a fashion inconsistent with historical activity, it may be indicative of induced seismicity as opposed to a natural occurrence. While natural seismic events are always of interest, the focus of the plan is on induced seismicity, which is less understood. Thus, the formula places more emphasis on possible induced events. The formula variables for "number", "local recursion", "regional recursion", and "recursion time" are used to address clustering and timing. The score for the number of earthquakes within a six-mile radius of a current earthquake event over the previous 30-day period is given twice the weight of the other factors. The rationale for the added weight is that the number of earthquakes gives an indication as to the degree of "clustering".

   Additionally, the recursion variables also attempt to discriminate between natural and induced seismic events. Recursion refers to the empirical observation that naturally occurring seismicity occurs in an exponential manner – for instance, every seismic event of magnitude 3 would be preceded by 10 magnitude 2 events and 100 magnitude 1 events. Recursion observations require the acquisition of a statistically significant number of earthquake events acquired over a relatively long term. A large number of events of similar size in a relatively short time period may be an indicator of induced (as opposed to natural) seismicity. Thus, natural recursion rates get a lower score than rates that are apparently not natural.

   The local recursion (within 6 miles of an event) gives some idea as to activity within the location accuracy of most current regional networks, while the regional recursion looks at all data for Kansas recorded over the last 35 plus years on the KGS database from the USGS, the Oklahoma Geological Survey, and KGS. Both variables are important in ascertaining if activity is part of an overall regional, natural pattern of activity which would be of interest, and the more important localized activity which is the focus of this plan.

   Lastly the "recursion time" variable places additional importance on multiple seismic events of similar size in a 24-hour period. Similar sized events are defined as those within magnitude 0.5 of each event (e.g. 2.0-2.5, 1.75-2.25, etc). Again, multiple, similar magnitude events in a short time period may be an indicator of induced (as opposed to natural) seismicity.

The magnitude data used in the SAS calculation will be derived from published data of acceptable quality to KGS.

Table 1 – Seismic Scores

	Risk Variables		Clustering Variables			
Score	**Felt**[1]	**Usable Structure**[2,3]	**Additional Number in Past 30 days**[3]	**Localized Natural**[4] **Recursion**[3]	**Regional Natural**[4] **Recursion (Kansas Database**[5]**)**	**Additional # of Events**[3] **+/- 0.5 Magnitude Over +/- 24 hrs**
0	No	No	0	yes	yes	0
1	Yes	Yes	1	no	no	1
2			2			2
3			3			3
4			≥4			4

1 *Based on USGS "Did You Feel It" web site or credible reports*
2 *Based on aerial mapping or field observation of man-made features that can be safely occupied by humans*
3 *Within a 6 mile radius*
4 *Natural from the axiom, for every 100 magnitude 1 seismic event there will be 10 magnitude 2s and 1 magnitude 3 seismic event*
5 *Kansas database includes all earthquakes recorded in Kansas since the 1970s by KGS, USGS, or OGS*

KGS will determine whether the SAS triggers further investigation. At a minimum, if the SAS is 10, or greater, KGS will proceed to Step C in the Plan.

The Task Force believes the value of "10" is conservative in that it will likely initiate reviews by the agencies that will result in a finding that no further action is needed. However, the Task Force believes it best to err on the side of caution until experience has been gained. Therefore, the SAS is subject to revision. As the agencies gain more experience, they will revise the trigger value as necessary.

If the SAS is less than 10, no further action is required.

C. If the SAS is 10 or greater, KGS notify KCC and KDHE the SAS threshold has been exceeded. KCC and KDHE will determine the locations of any disposal wells - generally within a 6 mile radius of the estimated epicenter of the triggering event. The KGS will also examine publicly available data to identify any known faults in the area.

D. Based on injection well data provided by KCC and KDHE, KGS will determine if there are any particular wells of interest that justify further evaluation. If there are, the Plan will proceed to Step F.

E. If there are no wells of interest, KGS will further explore and evaluate any geologic data, investigating whether the seismic activity is naturally occurring or is related to trigger(s) other than the disposal of fluids.

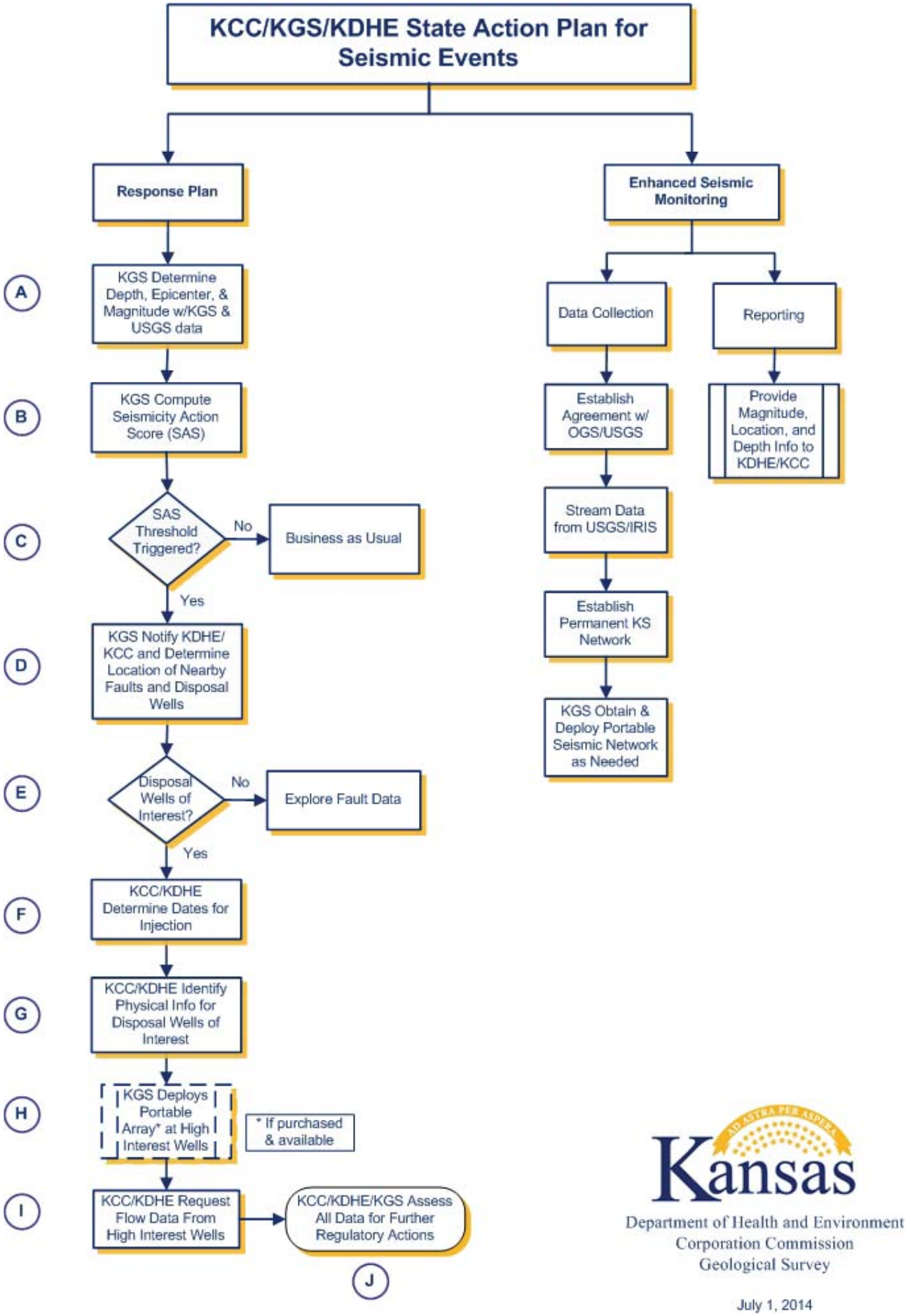
F. KGS will notify KCC and KDHE of any disposal wells of interest. KCC and KDHE will determine the injection history of the identified wells and provide that information to KGS.

G. KCC and KDHE will provide KGS any available information regarding the physical attributes of the disposal wells of interest – depth, permitted volumes, logs, etc.

H. Based on the disposal well data supplied by KCC and KDHE, KGS will identify "high interest" disposal wells. KGS may recommend deploying a portable seismic array in the areas of high interest disposal wells.

I. KCC and KDHE may request more frequent reporting on volume of fluids disposed in the high interest disposal wells from the well operators.

J. KGS, KCC, and KDHE will evaluate all available data and determine whether any of the regulatory remedies available under current statutory authorities are necessary.


KCC/KGS/KDHE State Action Plan for Seismic Events
Response Plan
Enhanced Seismic Monitoring
A
KGS Determine Depth, Epicenter, & Magnitude w/KGS & USGS data
B
KGS Compute Seismicity Action Score (SAS)
C
SAS Threshold Triggered?
No
Business as Usual
Yes
D
KGS Notify KDHE/ KCC and Determine Location of Nearby Faults and Disposal Wells
E
Disposal Wells of Interest?
No
Explore Fault Data
Yes
F
KCC/KDHE Determine Dates for Injection
G
KCC/KDHE Identify Physical Info for Disposal Wells of Interest
H
KGS Deploys Portable Array* at High Interest Wells
* If purchased & available
I
KCC/KDHE Request Flow Data From High Interest Wells
KCC/KDHE/KGS Assess All Data for Further Regulatory Actions
J
Data Collection
Reporting
Establish Agreement w/ OGS/USGS
Provide Magnitude, Location, and Depth Info to KDHE/KCC
Stream Data from USGS/IRIS
Establish Permanent KS Network
KGS Obtain & Deploy Portable Seismic Network as Needed
Kansas
Department of Health and Environment
Corporation Commission
Geological Survey
July 1, 2014